Argonne NATIONAL LABORATORY

ATLAS Searches for New Physics at 13 TeV

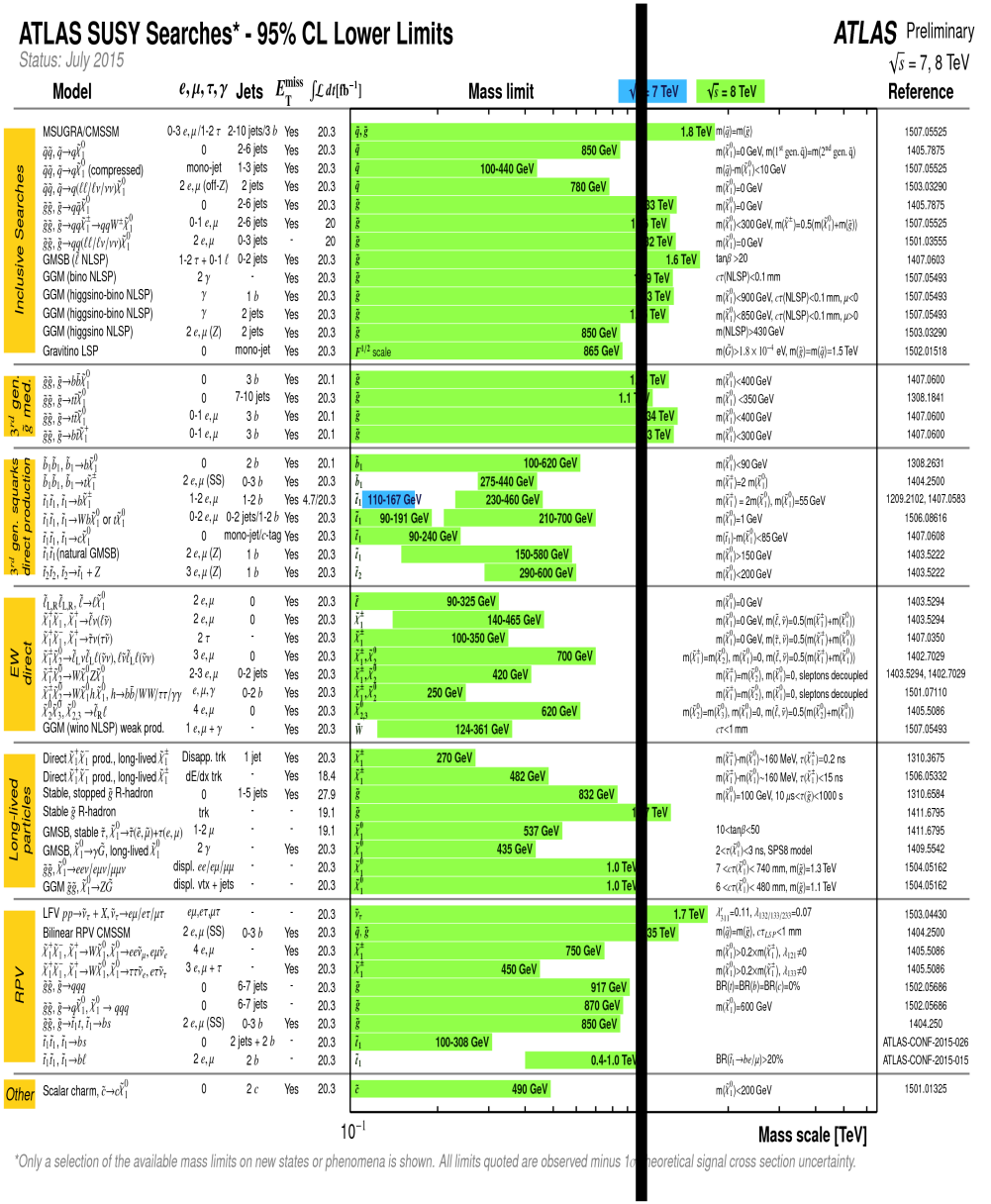
Jeremy Love

On Behalf of the ATLAS Collaboration

U.S. DEPARTMENT OF ENERGY

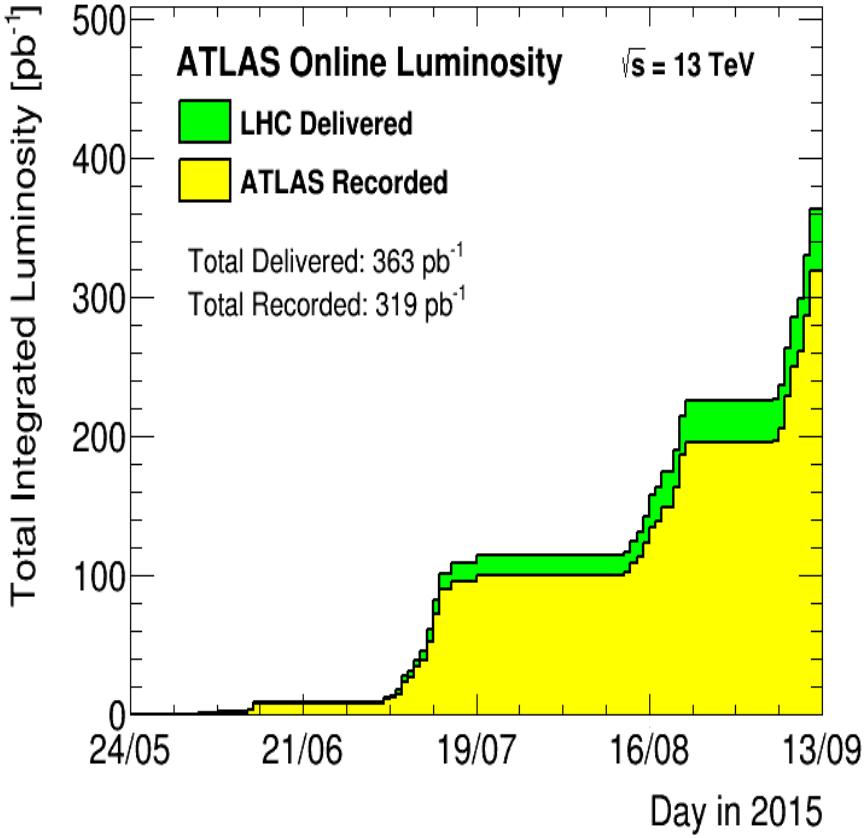
Status After Run-I

- Other than the SM Higgs no new particles discovered
- Limits of most Run-I searches around 1-2 TeV
  - Both SUSY and other BSM Theories
- Look to Run-II to discover what is beyond the SM
- Many search channels not yet sensitive but relaxed cuts have been used to validate analysis techniques and control regions

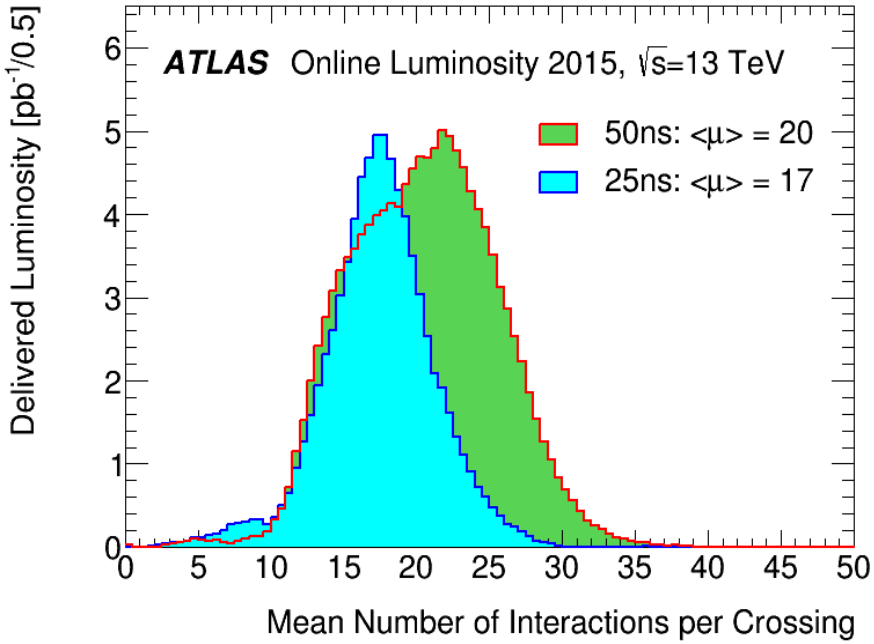


1 TeV

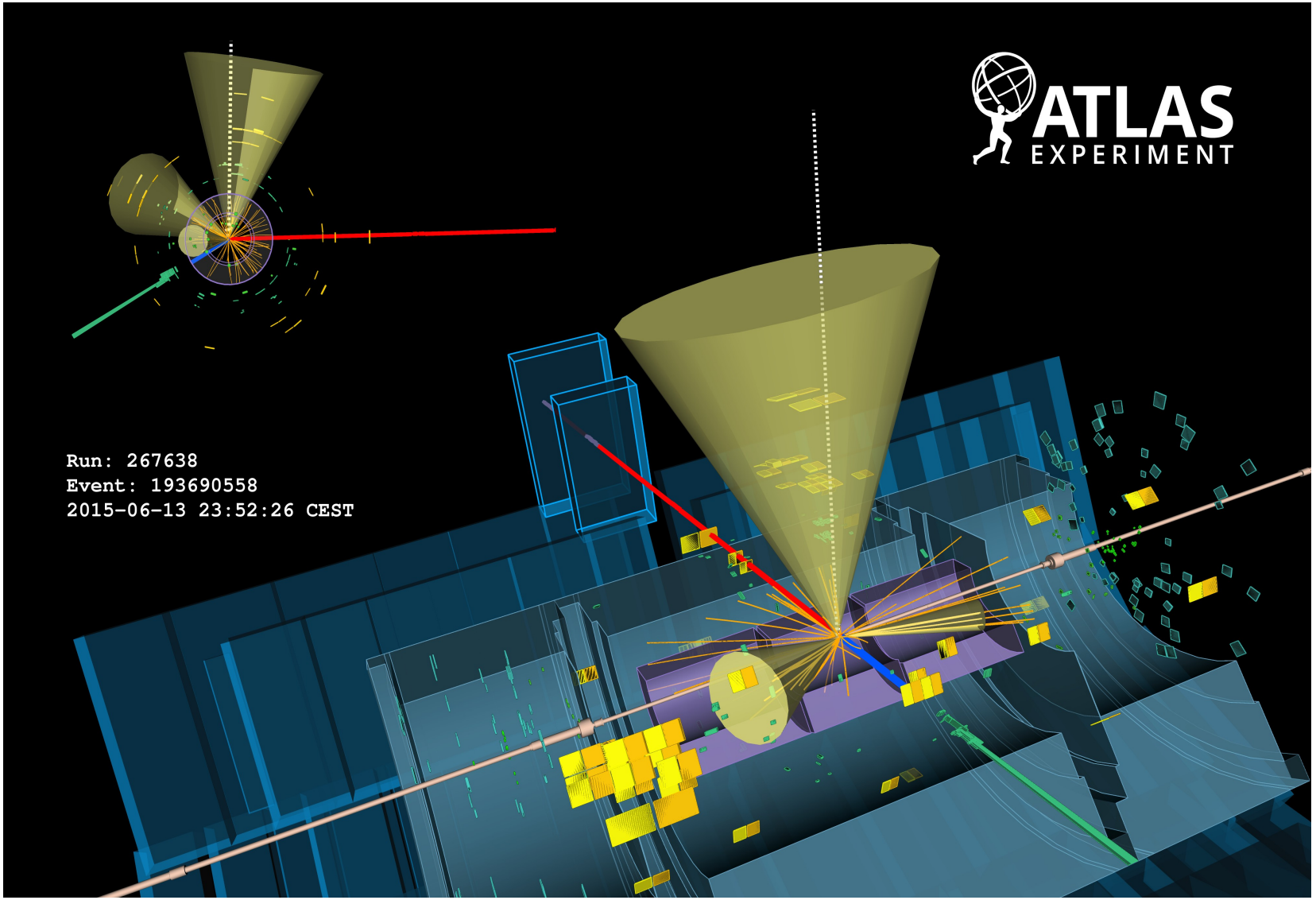
LHC Run-II



- ATLAS has recorded a total of 319 pb^{-1} recorded
- Two data taking periods already used for physics
  - 50 ns with $\langle\mu\rangle = 20$
  - 25 ns with $\langle\mu\rangle = 17$
  - Results shown for one or the other



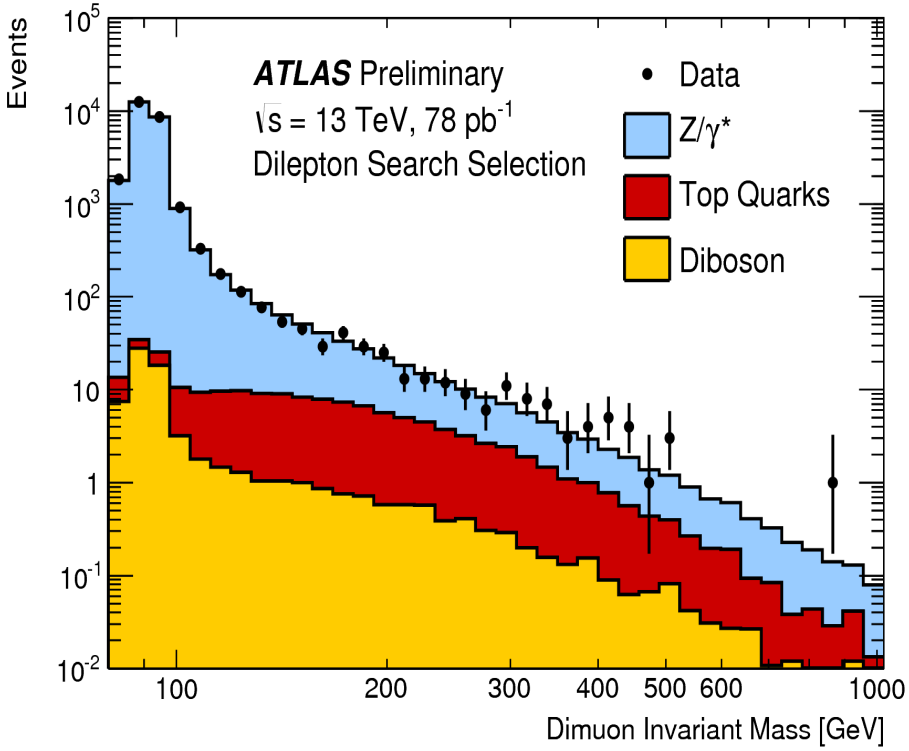
First Look at New Energies



Di-Lepton Final States (ee, μμ)

EXOT-2015-001

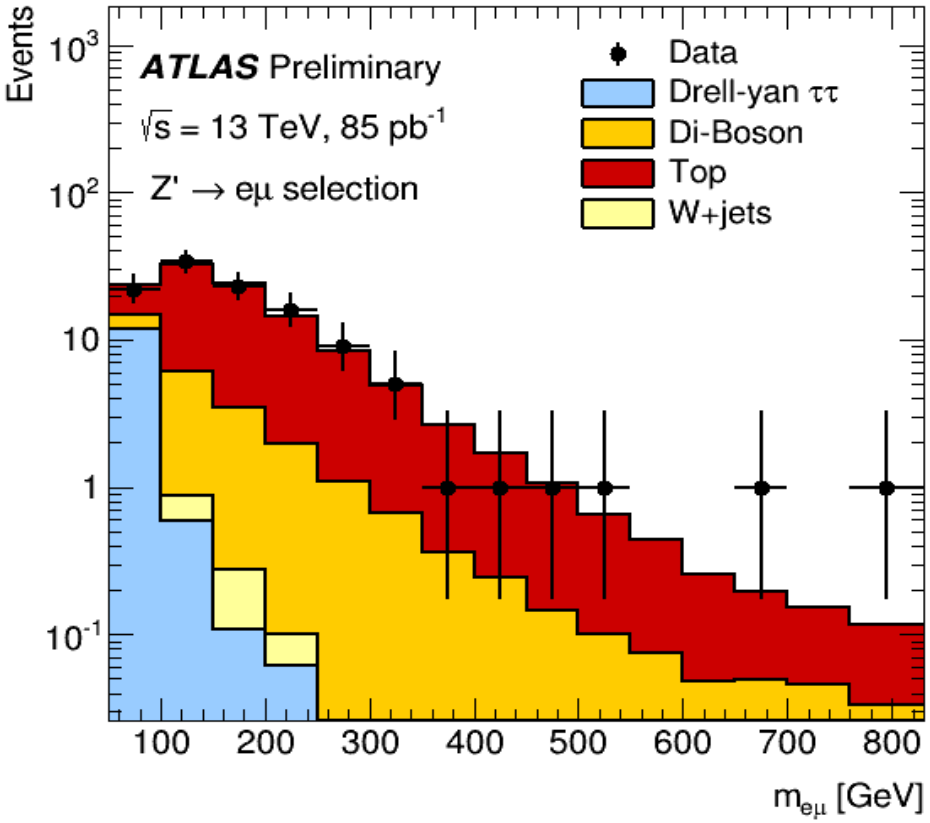
- Search for neutral resonances decaying to lepton pairs
  - Sign of a new fundamental symmetry
- Single lepton trigger selects events
  - Require two isolated leptons
    - p_T > 30 GeV, & $|\eta|$ < 2.5
- Calculate invariant mass of lepton pairs
  - Normalize MC prediction to observed data in window around the Z peak
    - 80 < m_{ll} < 120 GeV
- Highest mass di-electron event at 740 GeV
- Highest mass di-muon event at 881 GeV



Di-Lepton Final States (eμ)

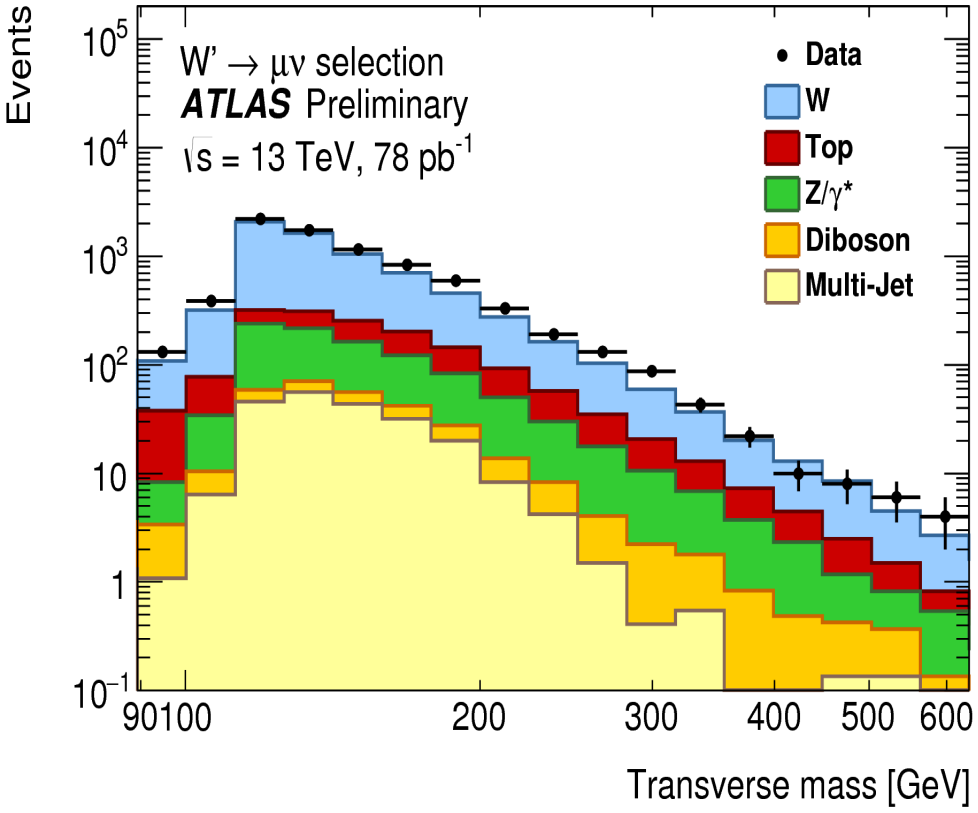
EXOT-2015-004

- Search for lepton flavor violation in charged lepton sector
- Single lepton trigger selects events
  - Require two opposite flavor leptons with p_T > 30 GeV
- Calculate invariant mass of lepton pairs
  - Normalize MC prediction to observed data in low mass region
    - M_{ll}< 300 GeV



Di-Lepton Final States (eν, μν)

EXOT-2015-002

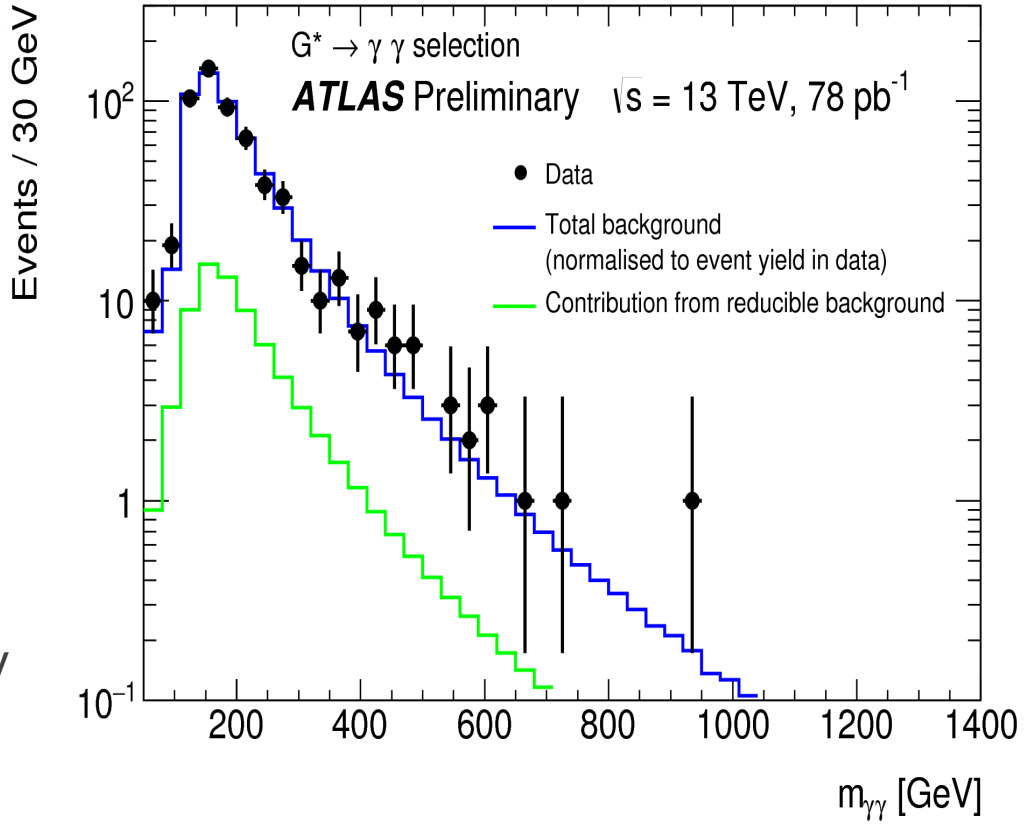


- Search for charged resonances decaying to lepton pairs
  - Sign of a new fundamental symmetry
- Single lepton trigger selects events
  - Require one charged lepton with p_T > 65 (55) GeV for e(μ)
  - Balanced by missing transverse momentum
- Calculate transverse mass of lepton pairs
- Highest transverse mass event in electron channel 1050 GeV
- Highest transverse mass event in muon channel 966 GeV

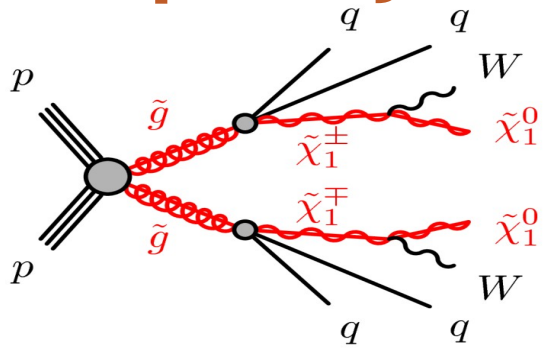
Di-Photon Final States

EXOT-2015-003

- Search for new resonances decaying to pair of photons
  - Ex: RS Gravitons
- Photons must be isolated in calorimeter and have E_T > 55 GeV
- Calculate invariant mass of photon pairs
  - Normalize MC to observed number of data events
- Highest mass photon pair is 940 GeV

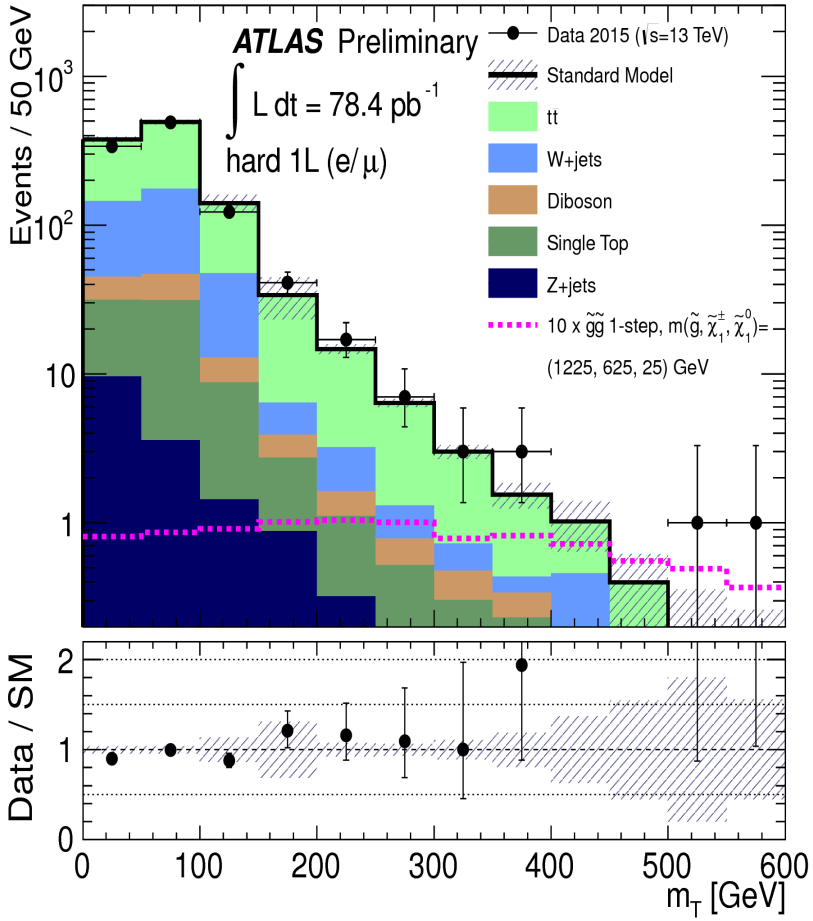


One Lepton, Jets, & Missing Energy



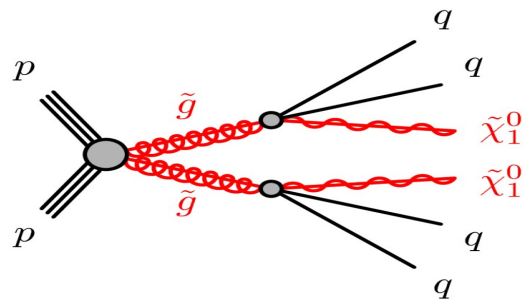
Run-I: 1501.03555/1507.05525

- Search for colored super partners
  - Calibration and validation of control regions
- Ultimately searches for squarks and gluinos in final states with jets, missing transverse momentum, and one lepton
- Calculate transverse mass in high multiplicity events
  - One isolated lepton p_T > 30 GeV
  - 2-4 jets p_T > 30 GeV
  - E_t^{miss} > 100 GeV
- Sensitivity over the Run-I search expected with ~3 fb^{-1}



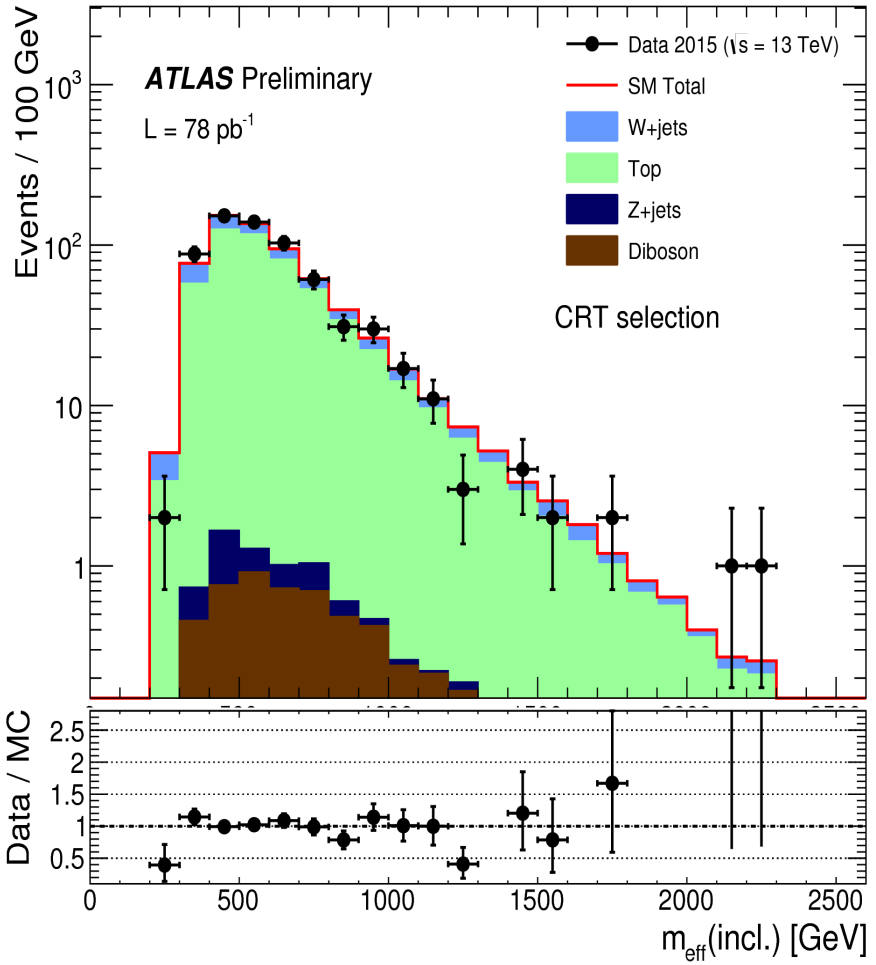
ATL-PHYS-PUB-2015-028

No Leptons 2-4 Jets + Missing Energy

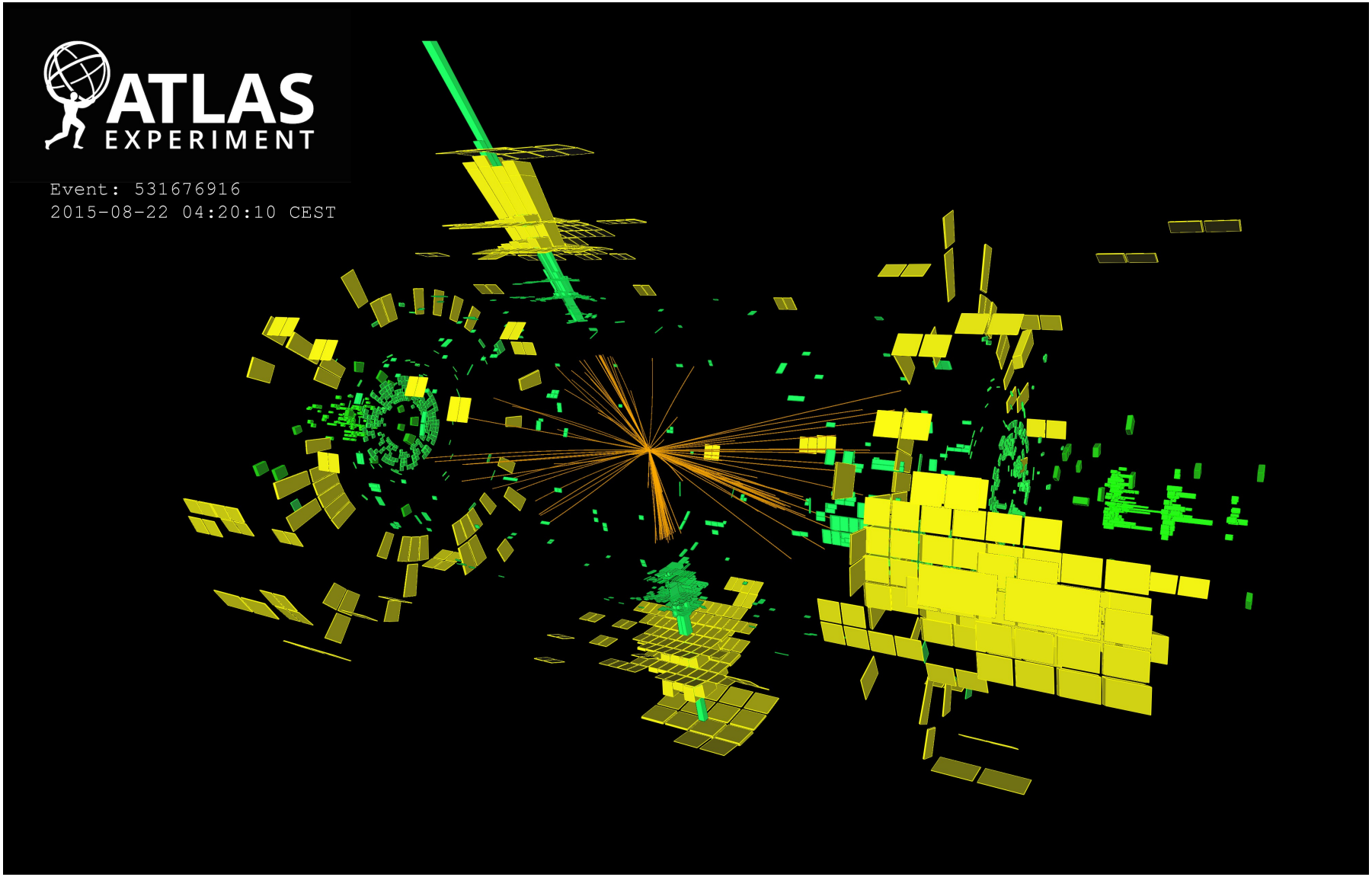


Run-1: 1405.7875/1507.05525

- Search for colored super partners
  - Calibration and validation of control regions
- Ultimately searches for squarks and gluinos in final states with jets, and missing transverse momentum
- Calculate scalar sum of transverse momentum of objects in events m_{eff}
  - Three control regions for W, Z, and top events
- Top control region selected with m_T requirement
  - $30 < m_T < 100$ GeV
- Good purity in background control regions
- MC distributions normalized to the observed data
- Sensitivity over Run-I search expected with ~3 fb^{-1}

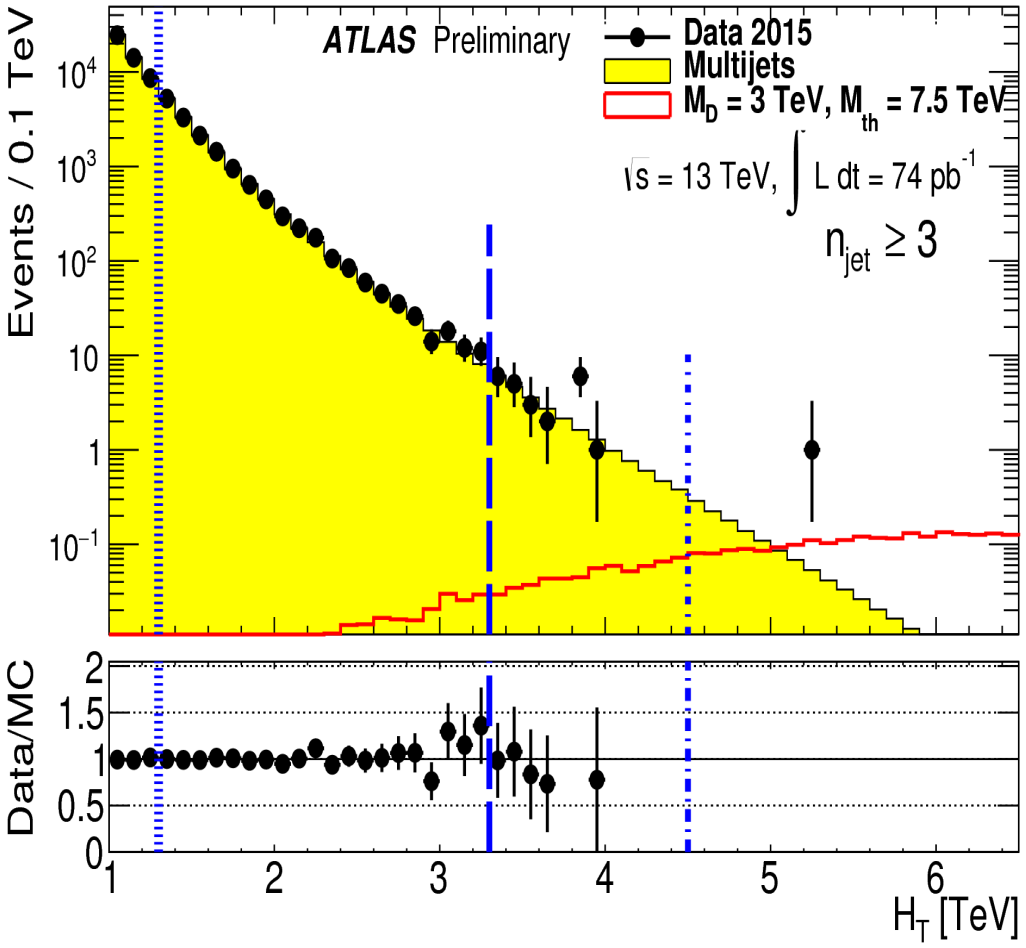


Search Results

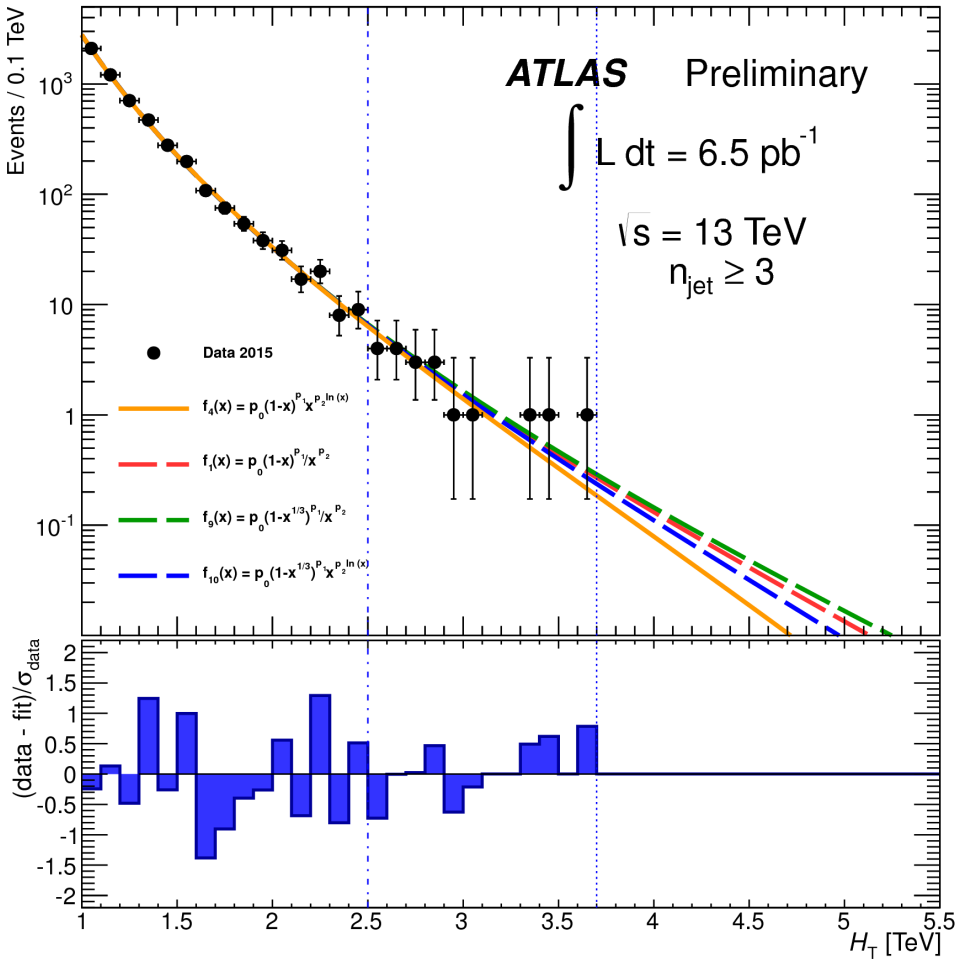


Search for Evidence of Strong Gravity

- Search for evidence of strong gravity in jet multiplicity bins
  - Dramatic threshold signals
- Require events to have at least three jets with p_T > 30 GeV
- Calculate scalar p_T sum of jets in the event H_T
  - MC is normalized to observed Data in low-H_T control region
  - Normalization is validated in intermediate-H_T region
  - Extrapolated into signal region at high-H_T
- Spectrum is fit with analytic functions
  - Signal is searched for by testing consistency in high-H_T signal region
  - Data split into two periods 6.5 pb^{-1} for validation and 74 pb^{-1} for search



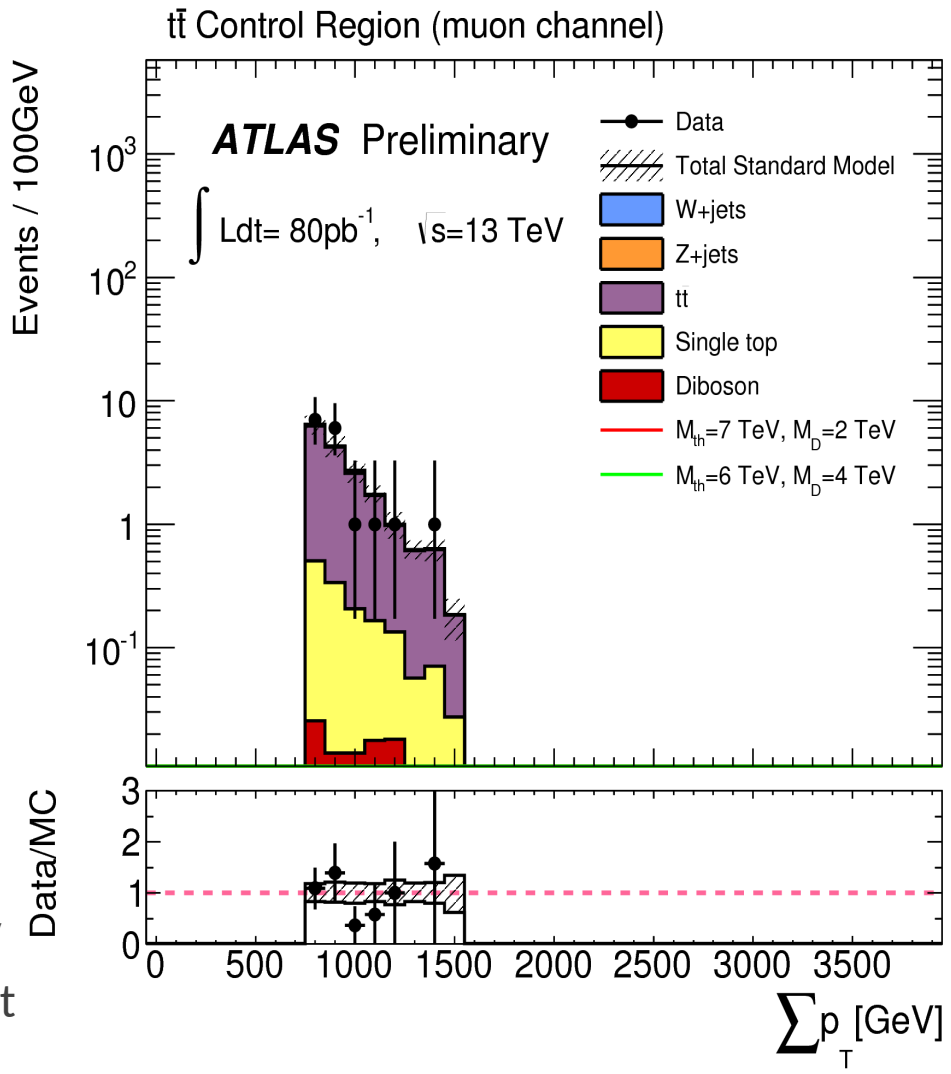
Search for Evidence of Strong Gravity – Results



- Jet multiplicity bins combined for final fit
  - Expect 1.4 events in SR observe 1
- ***No significant deviation from background only hypothesis***
  - Set 95% CL limits on models of low scale gravity using CHARYBDIS2
    - 2D plane of M_D – M_{TH}

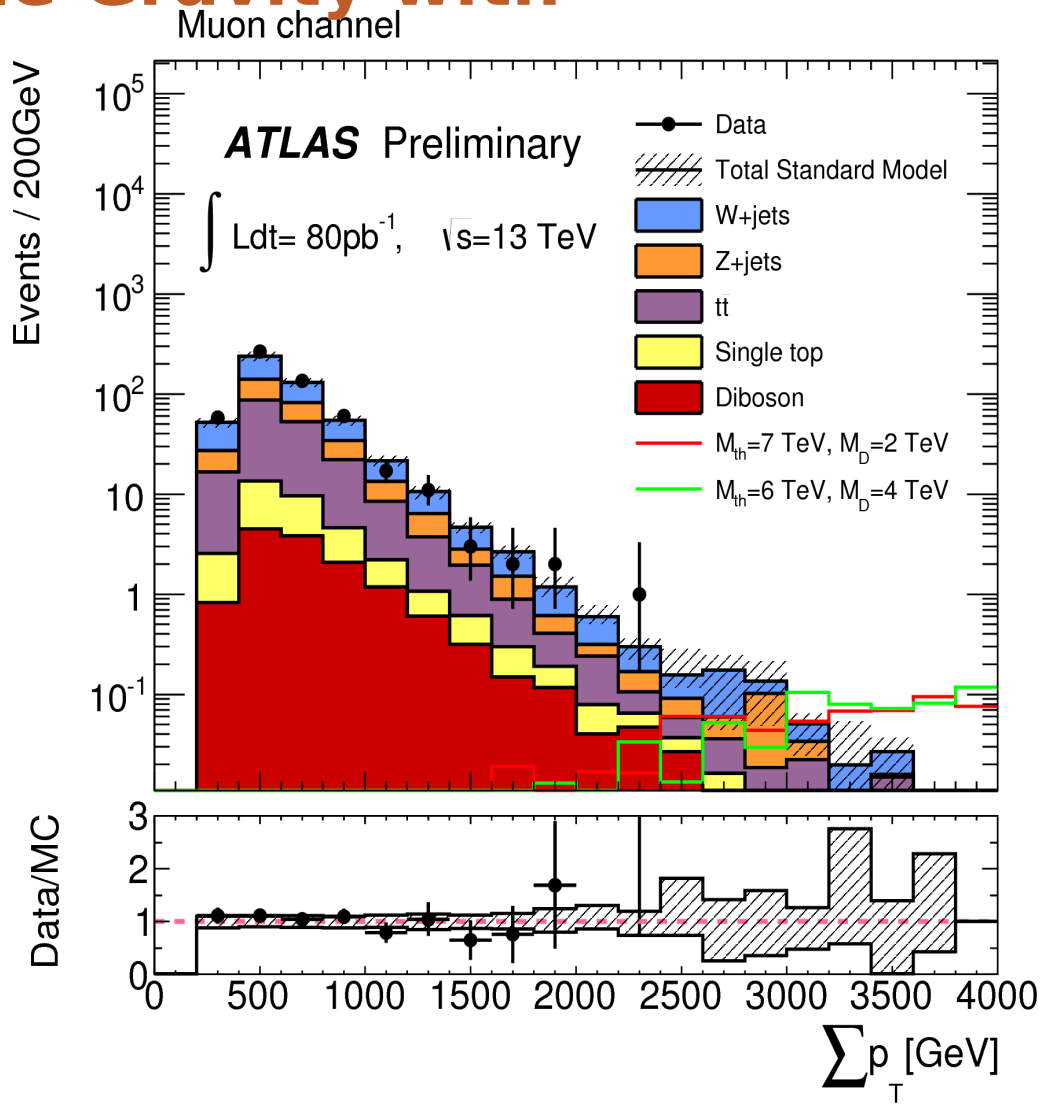
Search for TeV Scale Gravity with Leptons and Jets

- Search for evidence of strong gravity in H_T spectrum
  - Dramatic threshold signal
- Single lepton triggers select events
  - Events categorized based on highest p_T lepton
- Calculate H_T of all objects in the event
- Control Regions for W, Z, and top backgrounds
  - Validation Region to test consistency
- Signal Regions where lepton p_T > 100 GeV plus two other 100 GeV objects, and event H_T > 2 TeV or 3 TeV



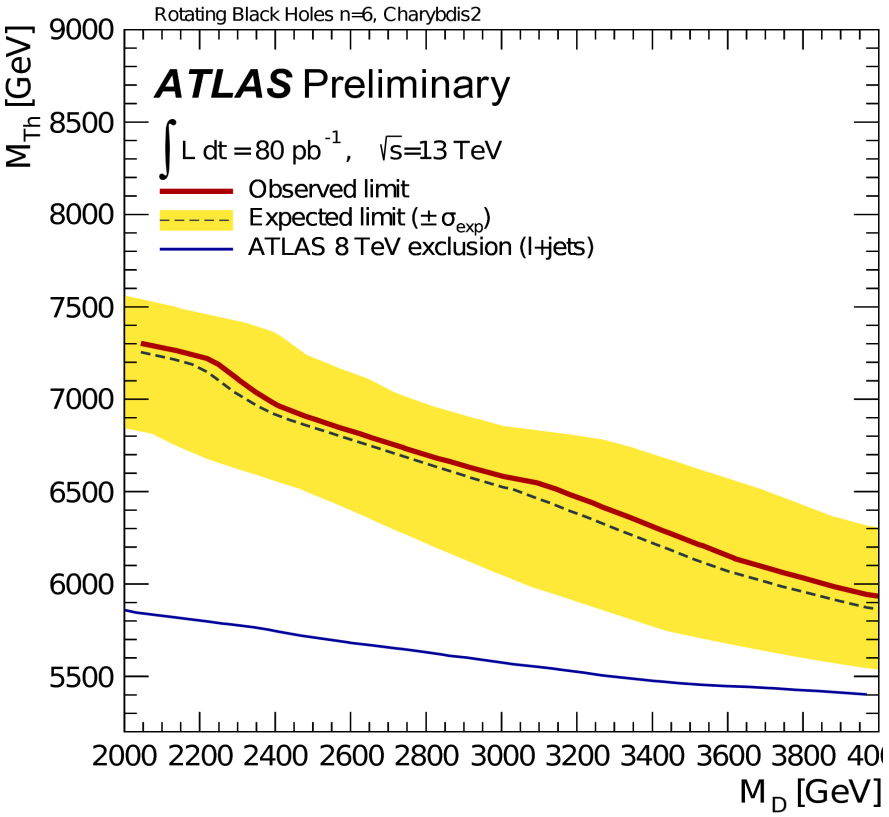
Search for TeV Scale Gravity with Leptons and Jets

- Control region fits are extrapolated to high H_T region
  - Profile likelihood fits of W, Z, top contributions
- Validation region w/ H_T between 1.5- 2.0 TeV
- Signal appears at high-H_T
- In 2(3) TeV Signal Regions expected 5.3 (0.3) event from SM fits
  - Observed 5 and 0
- ***No significant deviation from background only hypothesis***
  - Set 95% CL limits on models of rotating black holes using CHARYBDIS2
  - Limits set in 2D M_D vs M_{TH} plane

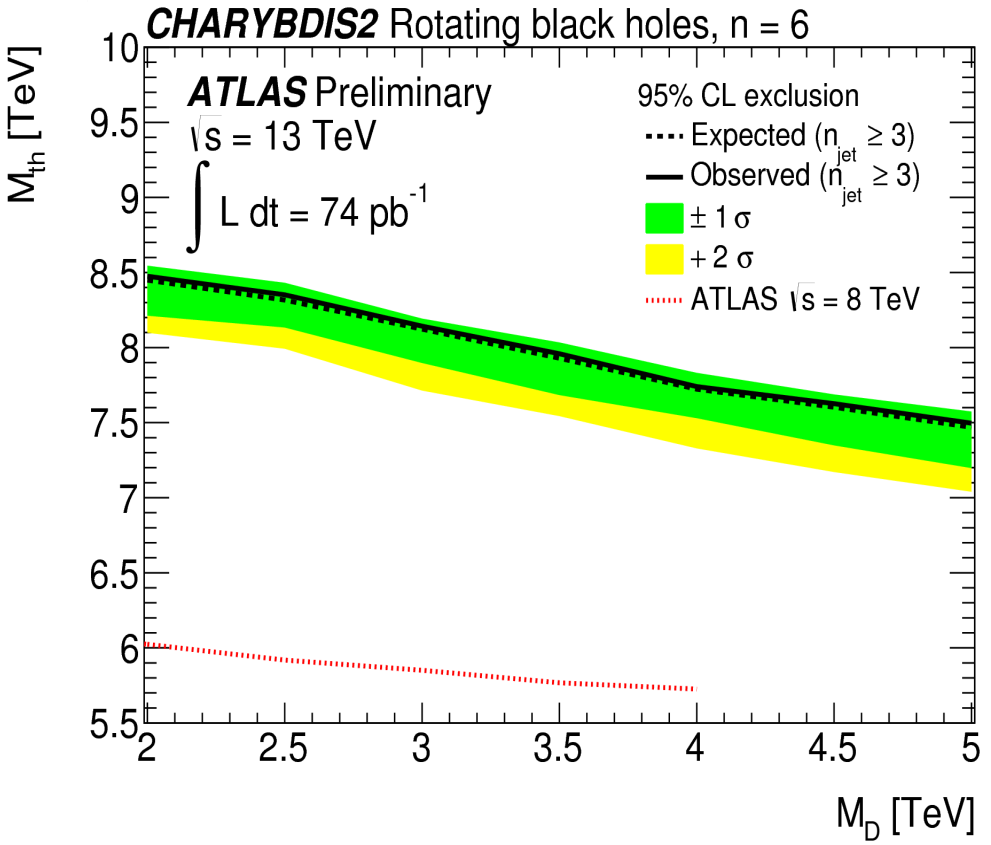


Search for TeV Scale Gravity – Results

ATLAS-CONF-2015-046



ATLAS-CONF-2015-043

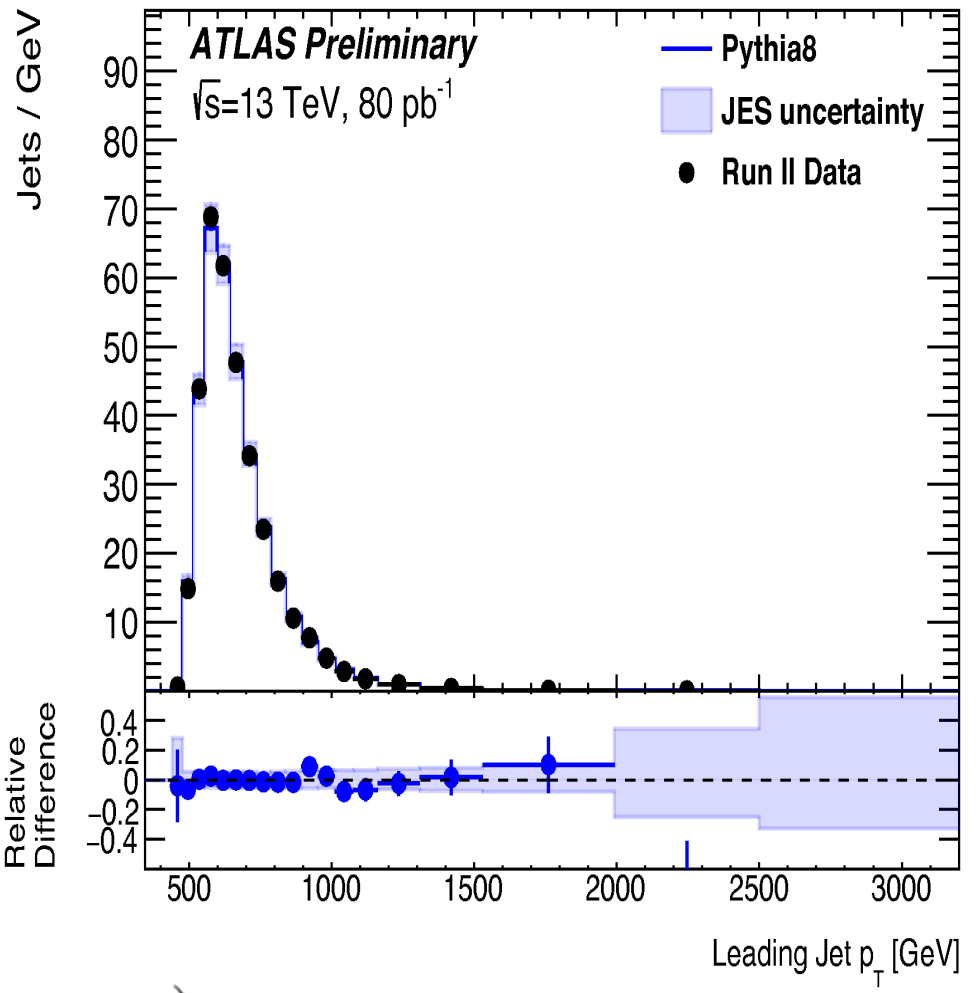


- In both leptonic and hadronic channels Run-II 95% CL limits already surpass Run-I analysis!

Searches In Di-Jet Final States

ATLAS-CONF-2015-042

- Search for non-SM features in di-jet final states
  - New resonances in m_{jj}
  - Deviations in angular variables
- For resonance search
  - Select events with leading(subleading) jet has p_T > 410(50) GeV and $|y^*|$ < 0.6
  - Calculate invariant mass m_{jj}
- For angular analysis
  - Select events with leading(subleading) jet has p_T > 410(50) GeV and $|y^*|$ < 1.7 and $|y_B|$ < 1.1
  - Calculate angular variable χ

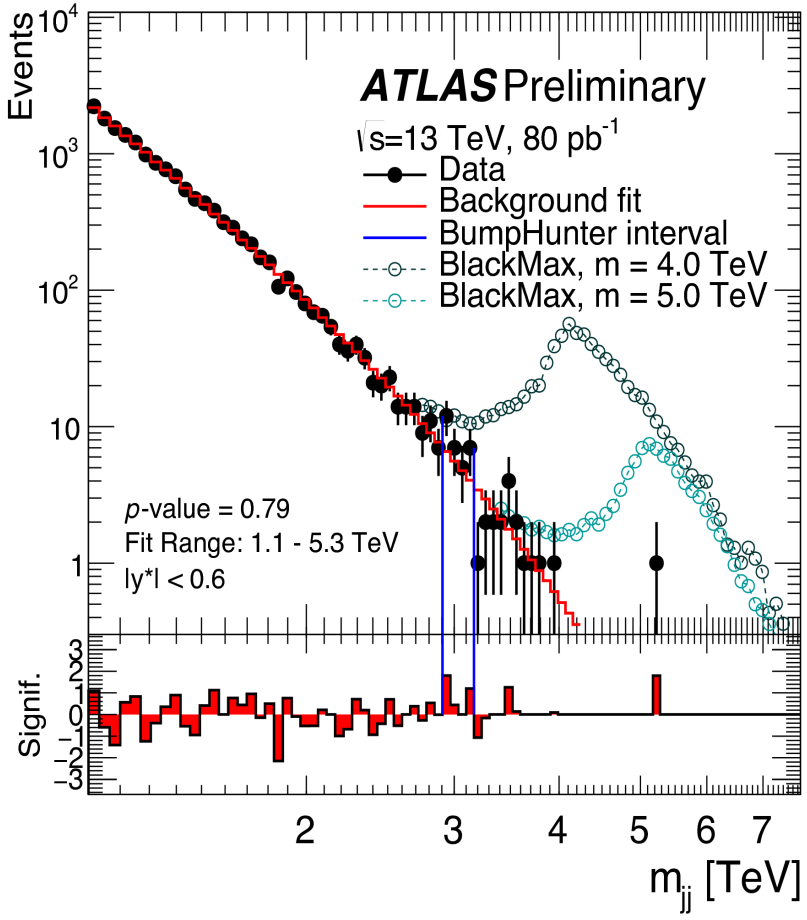


$$y^* = \frac{1}{2}(y_1 - y_2)$$

Di-Jet Resonances Search

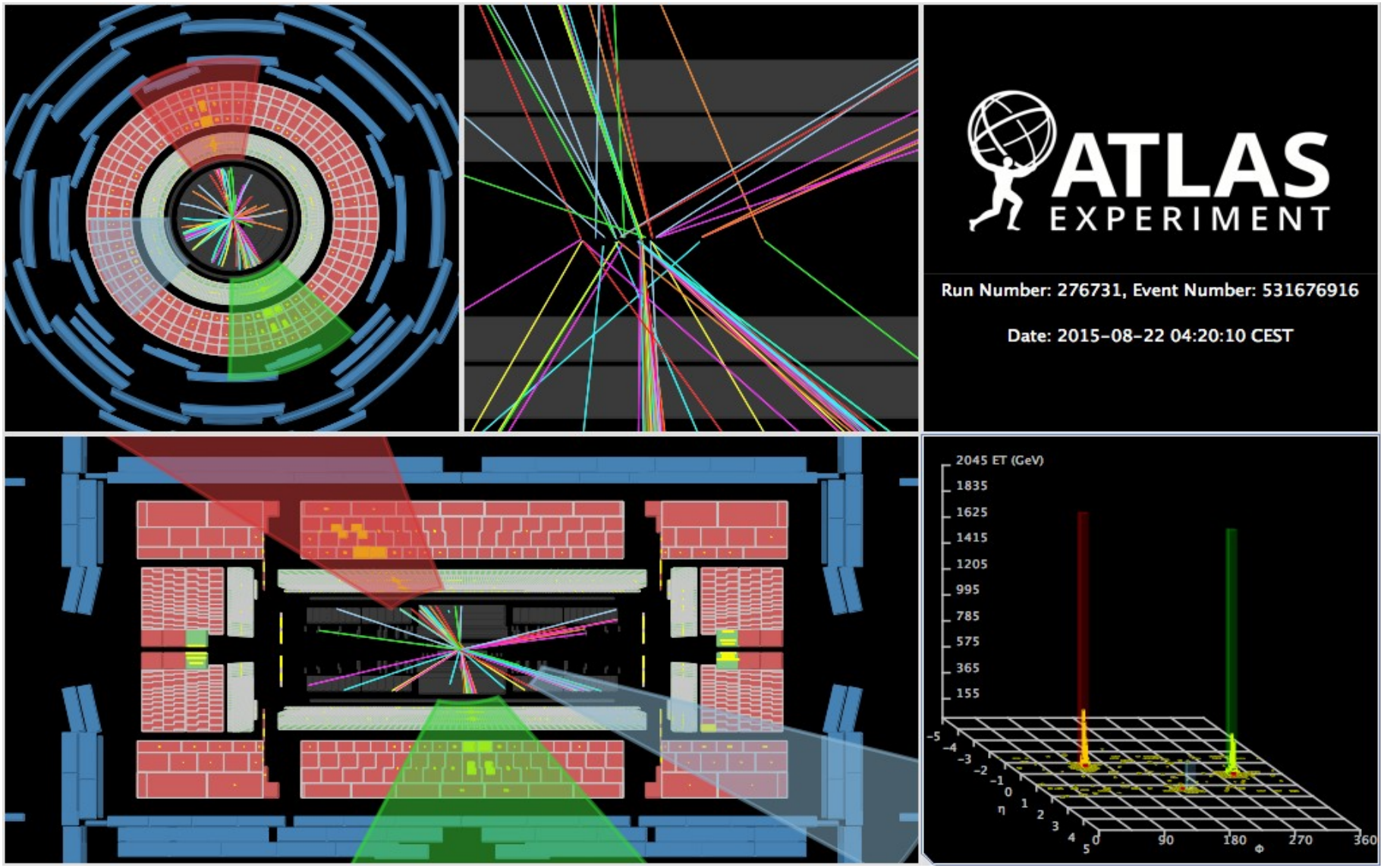
ATLAS-CONF-2015-042

$$f(z) = p_1(1-z)^{p_2} z^{p_3+p_4 \log z} \qquad z \equiv m_{jj}/\sqrt{s}$$



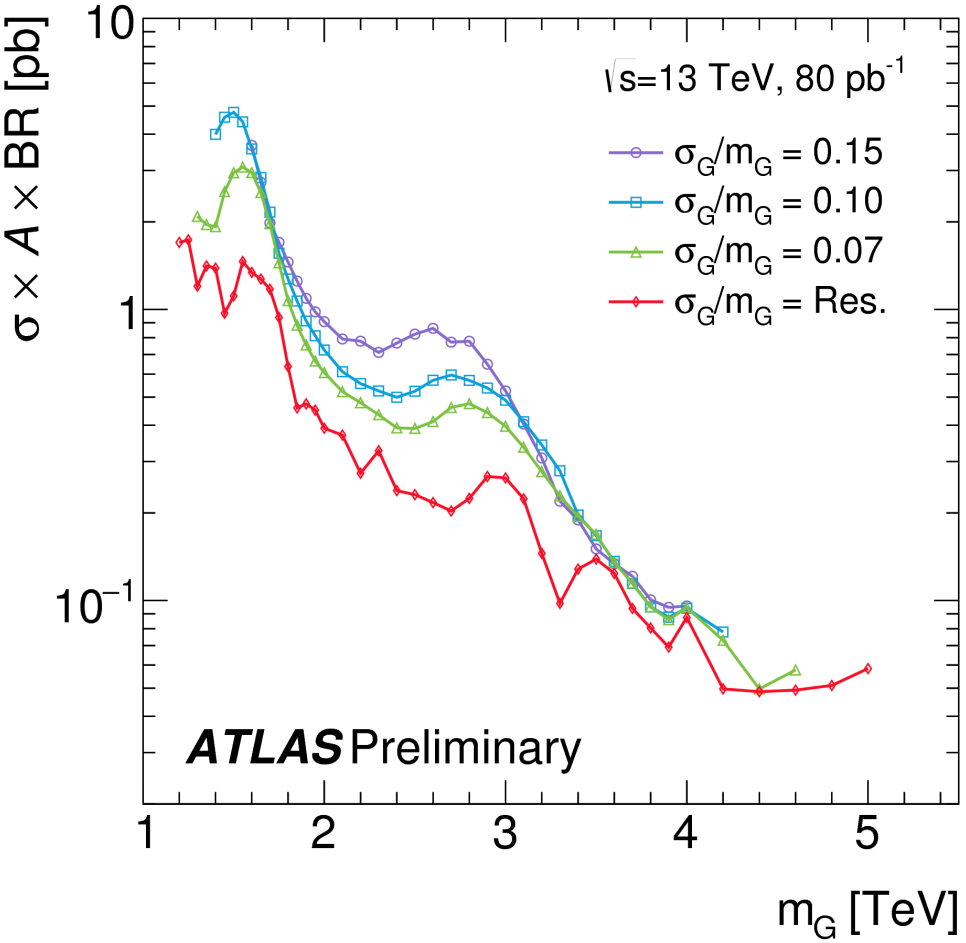
- Fit m_{jj} distribution with analytic function
- Compare fit with observed data using BumpHunter
  - Most discrepant region identified as 2.9 - 3.2 TeV
    - p-value of 0.76
- ***Consistent with background only hypothesis***
- Highest mass event is 5.2 TeV

Di-Jet Event with m_{jj} = 5.2 TeV!



Di-Jet Resonances Search - Results

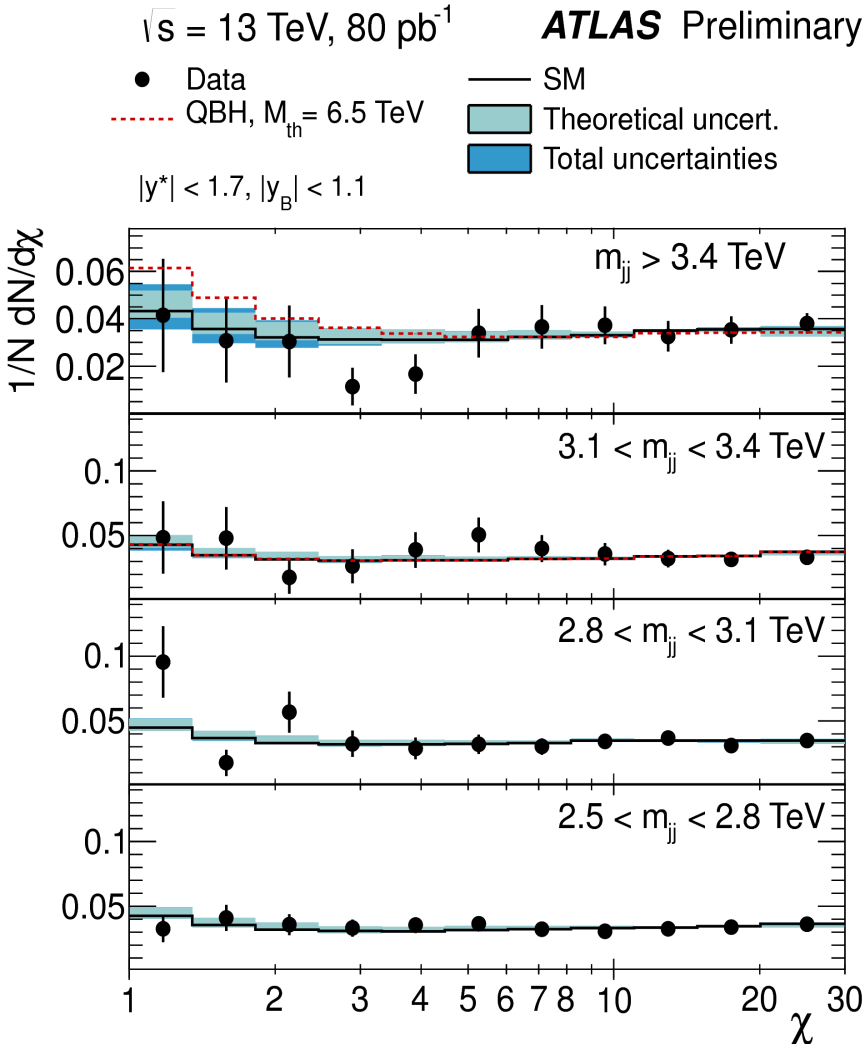
- 95% CL limits are derived for a Gaussian signal as function of resonance width
- Signal hypothesis for ADD Graviton using BlackMax and Quantum Black Hole MC generators
  - For all signals $M_D = M_{th}$ and n=6
- The resonant search excludes $M_{th} < 6.8$ TeV at 95% CL using QBH
  - Using BlackMax $M_{th} < 6.5$ TeV excluded at 95% CL



Di-Jet Angular Search

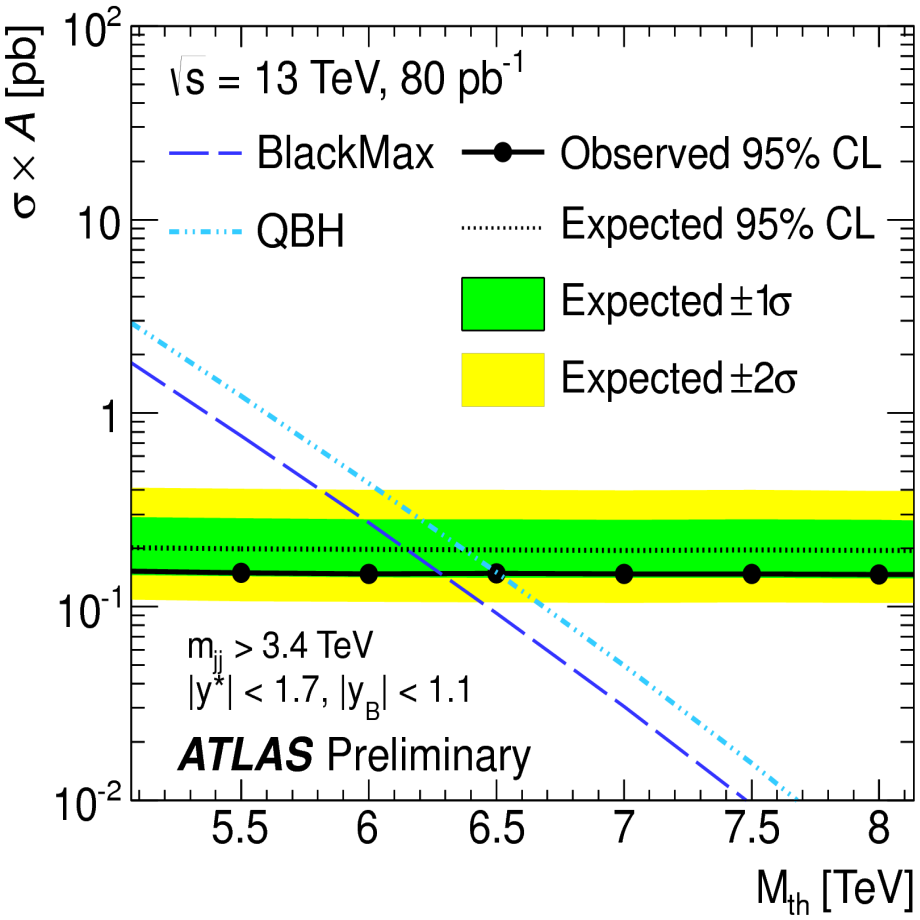
$$\chi = e^{2|y^*|} \sim \frac{1+\cos\theta^*}{1-\cos\theta^*}$$

- For events with m_{jj} over 2.5 TeV the χ distribution is tested for consistency with the SM
  - Performed in bins of m_{jj}
- SM prediction from PYTHIA8 corrected in m_{jj} and χ using NLOJET++
- QBH signal would appear as excess in low χ bins
- The p-value of the background only hypothesis to the data is 0.5
- ***No significant deviation is observed***



Di-Jet Angular Search - Results

ATLAS-CONF-2015-042



- 95% CL limits are derived for ADD models of gravity as function of M_{TH}
- The angular search excludes $M_{th} < 6.5$ TeV at 95% CL using QBH
  - Using BlackMax $M_{th} < 6.4$ TeV excluded at 95% CL

Summary and Conclusions

- ATLAS has recorded 319 pb^{-1} of 13 TeV data
  - Two periods of 80 pb^{-1} used in public results

- Re-establishing understanding of high momentum objects
  - Leptons, photons, jets, missing transverse momentum, H_T
- Relaxed cuts have been used to validate control regions and analysis techniques where sensitivity has not yet passed Run-I analyses

- Using the Run-II data ATLAS has performed searches in a number of final states
  - ***No significant deviation from the background only hypothesis is observed.***
  - Searching for signs of Strong Gravity in hadronic and lepton plus jets final states
    - Setting limits in a two dimensional plane
  - Search for Gaussian signal and Quantum Black Holes s in di-jet final state
    - Excluding M_{th} below 6.8 TeV using both a resonant search and angular analysis

- More searches are right around the corner!

Additional Material